



High Temporal Resolution Sediment Fingerprinting with Uncertainty: A Bayesian Approach

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Primary Research Aims

- Develop an improved fluvial sediment source apportionment technique.
 - How to **improve the temporal resolution** of source apportionment estimates whilst minimising analytical costs.
 - How to **consistently quantify all perceived uncertainties** associated with the sediment mixing model procedure.



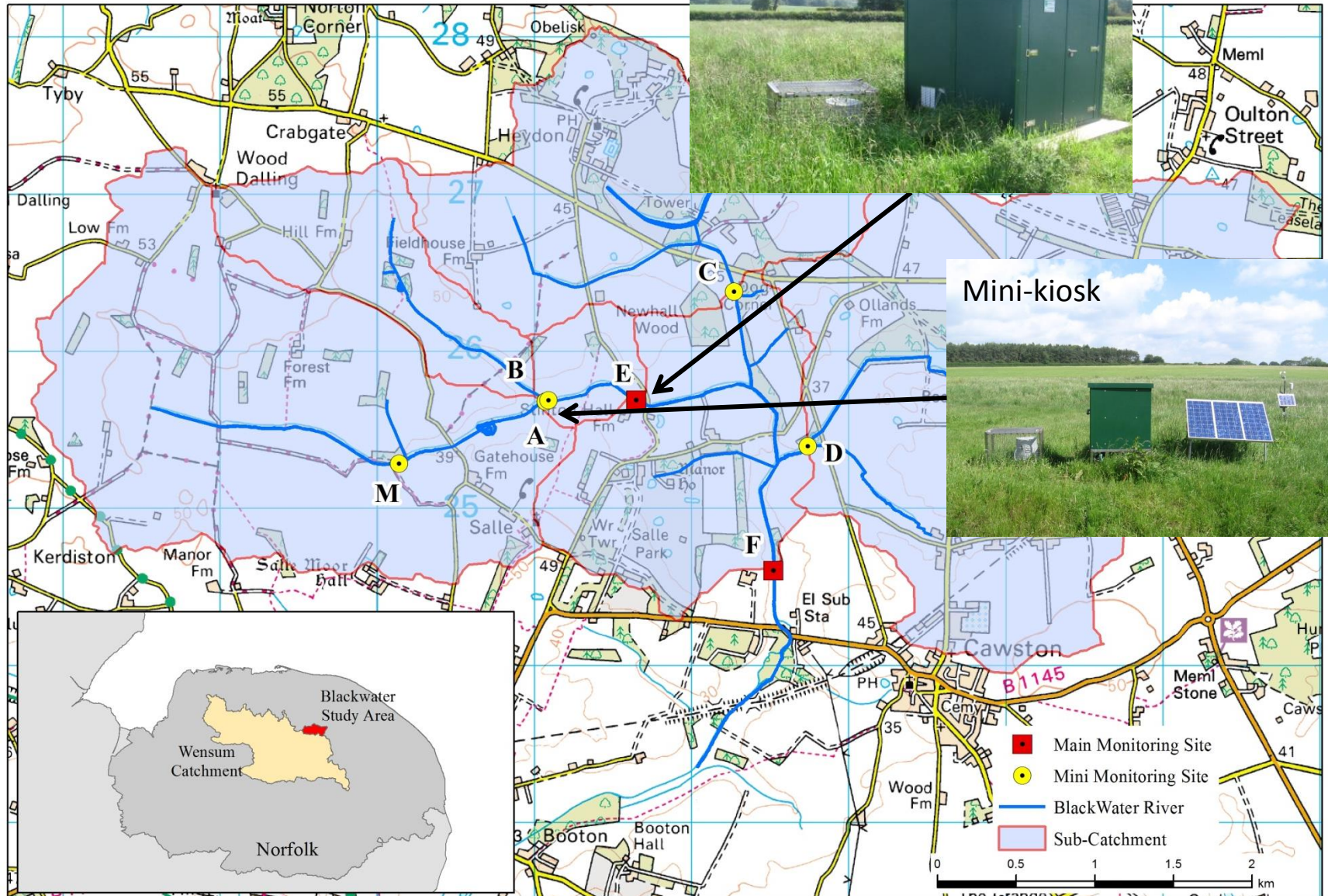
River Wensum Catchment



Blackwater Sub-Catchment

High-spec kiosk

~20 km²



What are the Possible Sources?

Channel Banks



**Suspended
Sediments**



Arable Topsoils



Field Drains



Road Verges



Collecting Sediments



- Instream **suspended sediment** samples collected during heavy rainfall events (>10 mm) via **ISCO automatic samplers** – 30-120 minute intervals

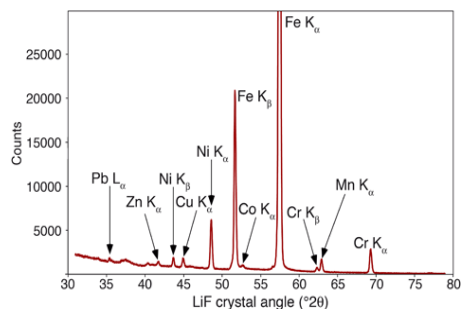
- Sediment samples collected from each of the **4 potential source areas** – surface scrapes (<50 mm) and grab samples.
 - Target **critical source areas**.



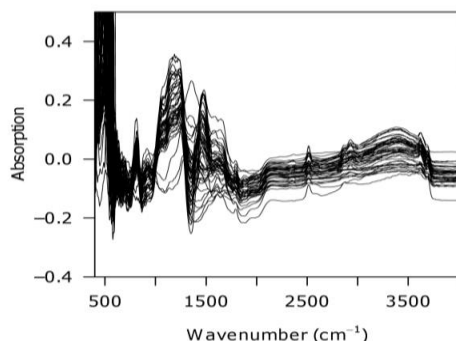
Analysing Geochemistry - Spectroscopy



All samples sonicated, wet sieved $<63 \mu\text{m}$, and vacuum filtered through **quartz fibre filter (QFF) papers**.



XRFS: X-ray Fluorescence Spectroscopy (Al, Ca, Ce, Fe, K, Mg, Mn, Na, P, Si, Ti) - 'Geochemical Fingerprints'.



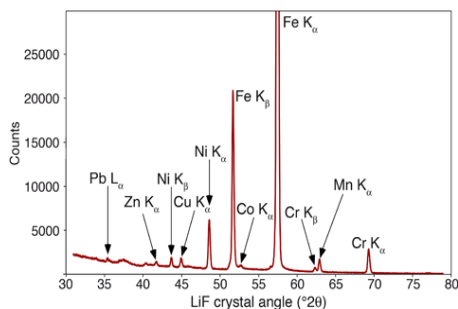
DRIFTS: Diffuse Reflectance Infra-red Spectroscopy - Organic Carbon, Fe/Al oxyhydroxides

- **Rapid, accurate, inexpensive and non-destructive** – contrast with ICP, acid digestion, LOI etc....

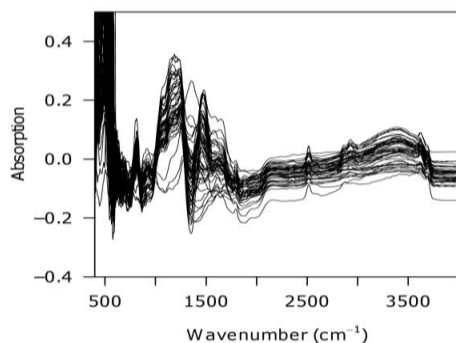
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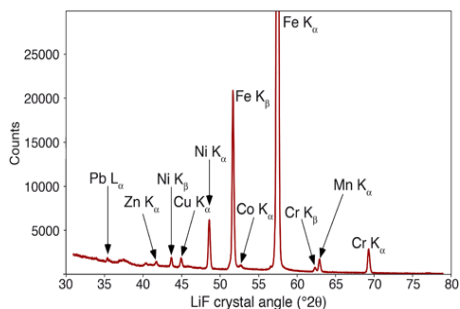
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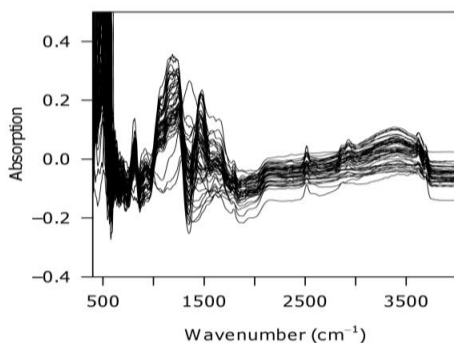
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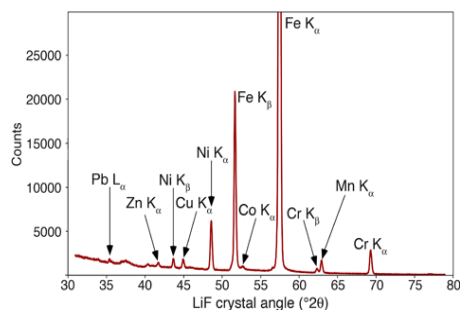
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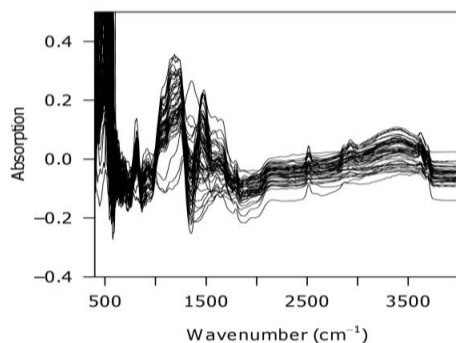
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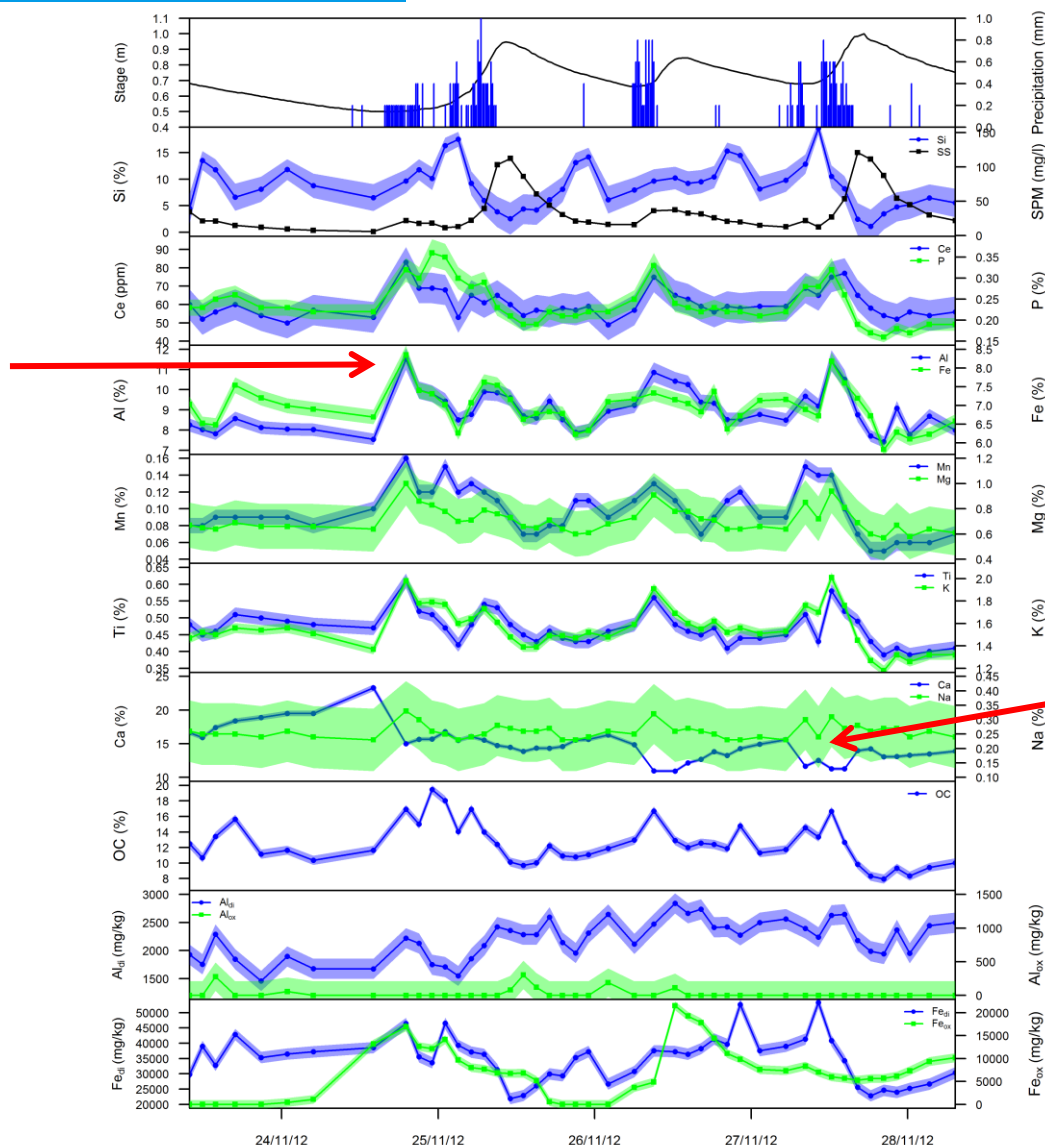


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High-resolution time series

Peaks in clay-mineral associated elements during rainfall – **indicative of surface sources**

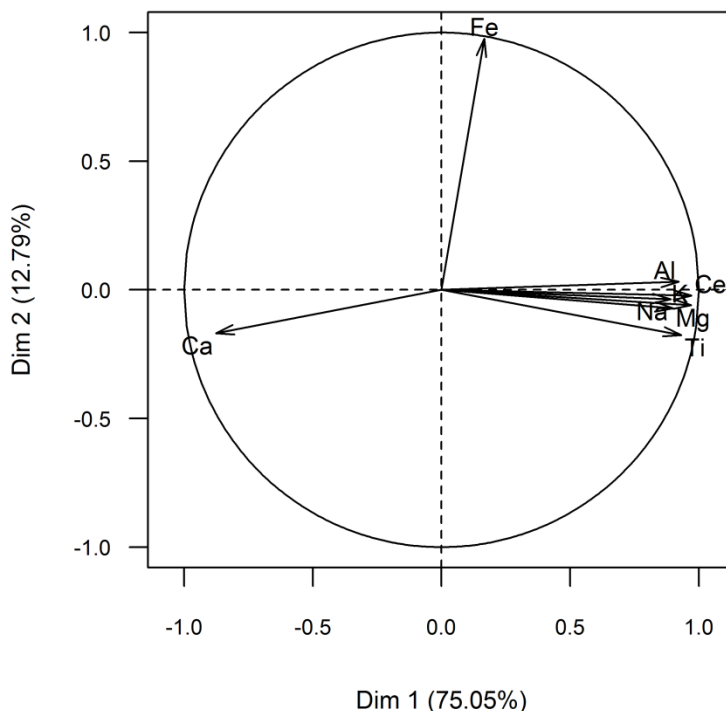
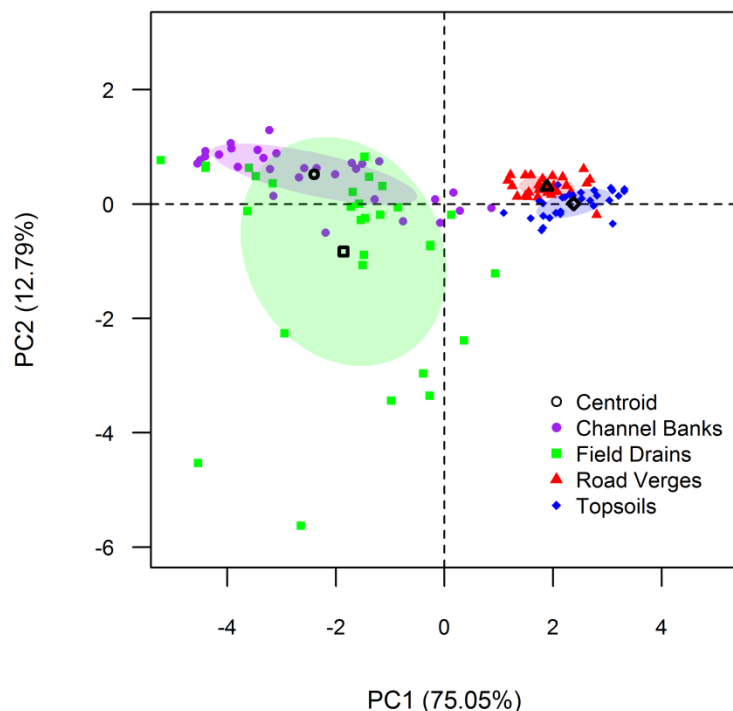


60-120 minute resolution

Decline in Ca – reduced importance of subsurfaces

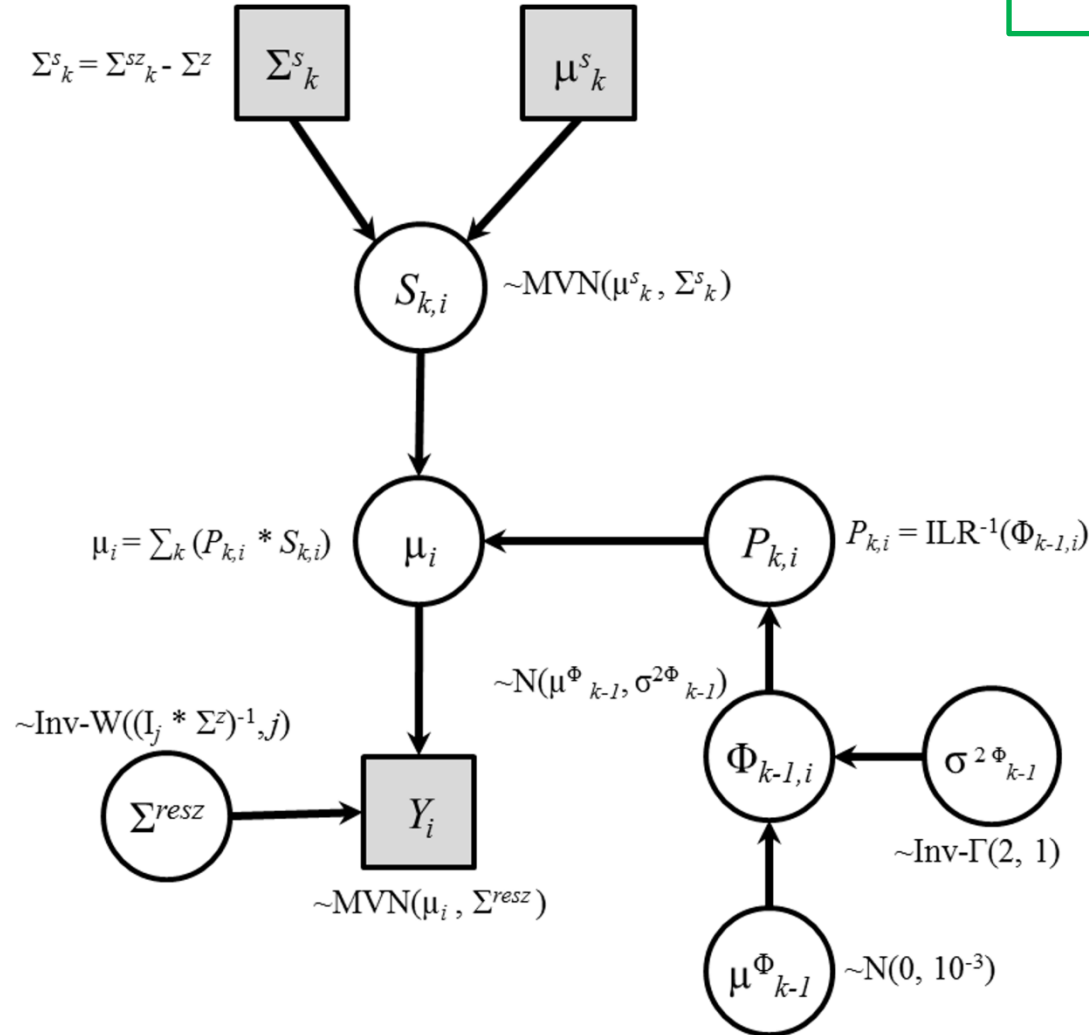
Identifying Fingerprints

- **Principal components analysis (PCA)** and **Linear Discriminant Analysis (LDA)** to determine geochemical fingerprints capable of differentiating the source areas.
- 8 geochemical fingerprints selected (**Ca, K, Mg, Al, Ce, Fe, Na, Ti**).
- **Channel bank** and **field drain** data merged into a combined **subsurface** sediment source.



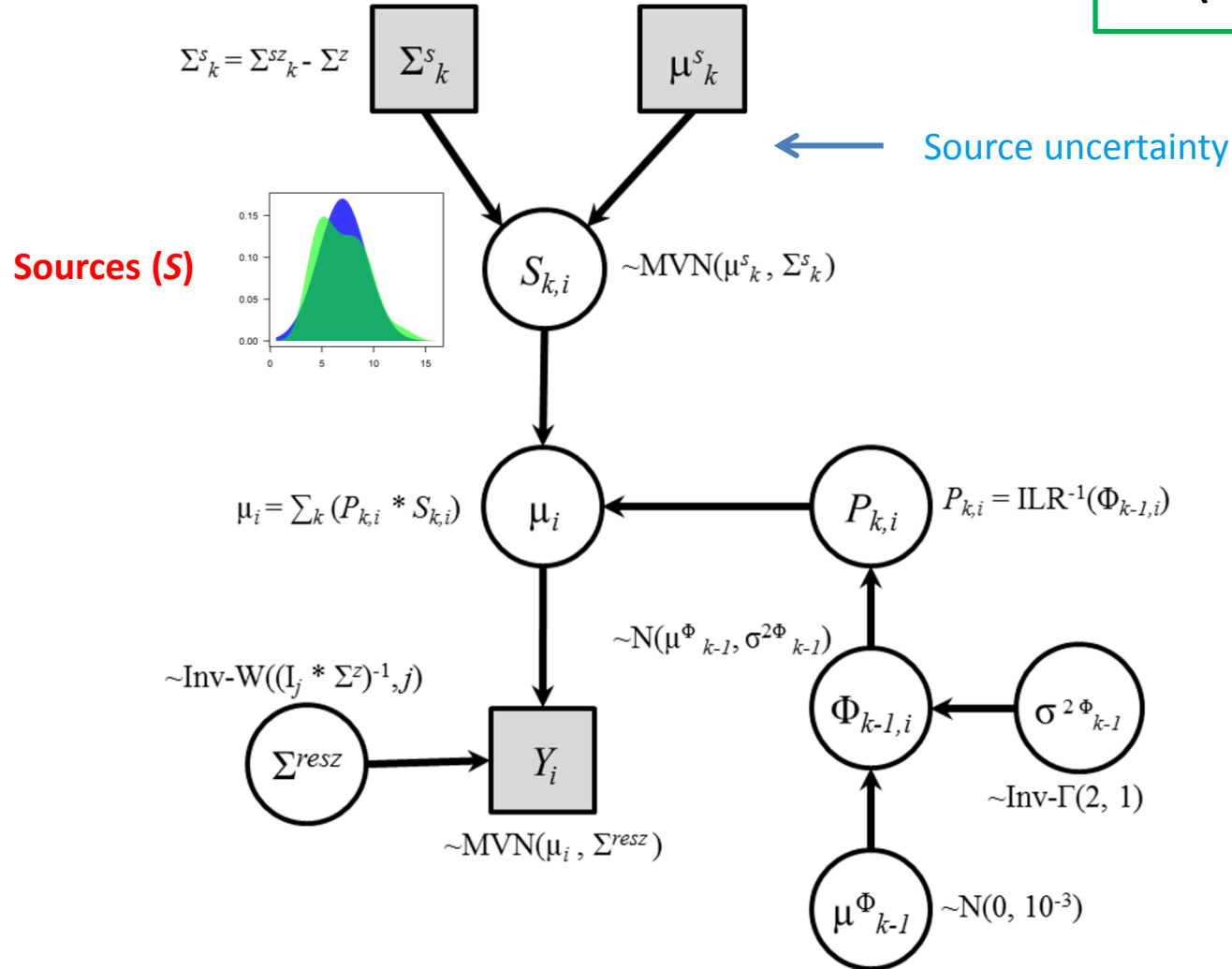
Bayesian Mixing Model

$$\mathcal{L}(S, P | Y)$$



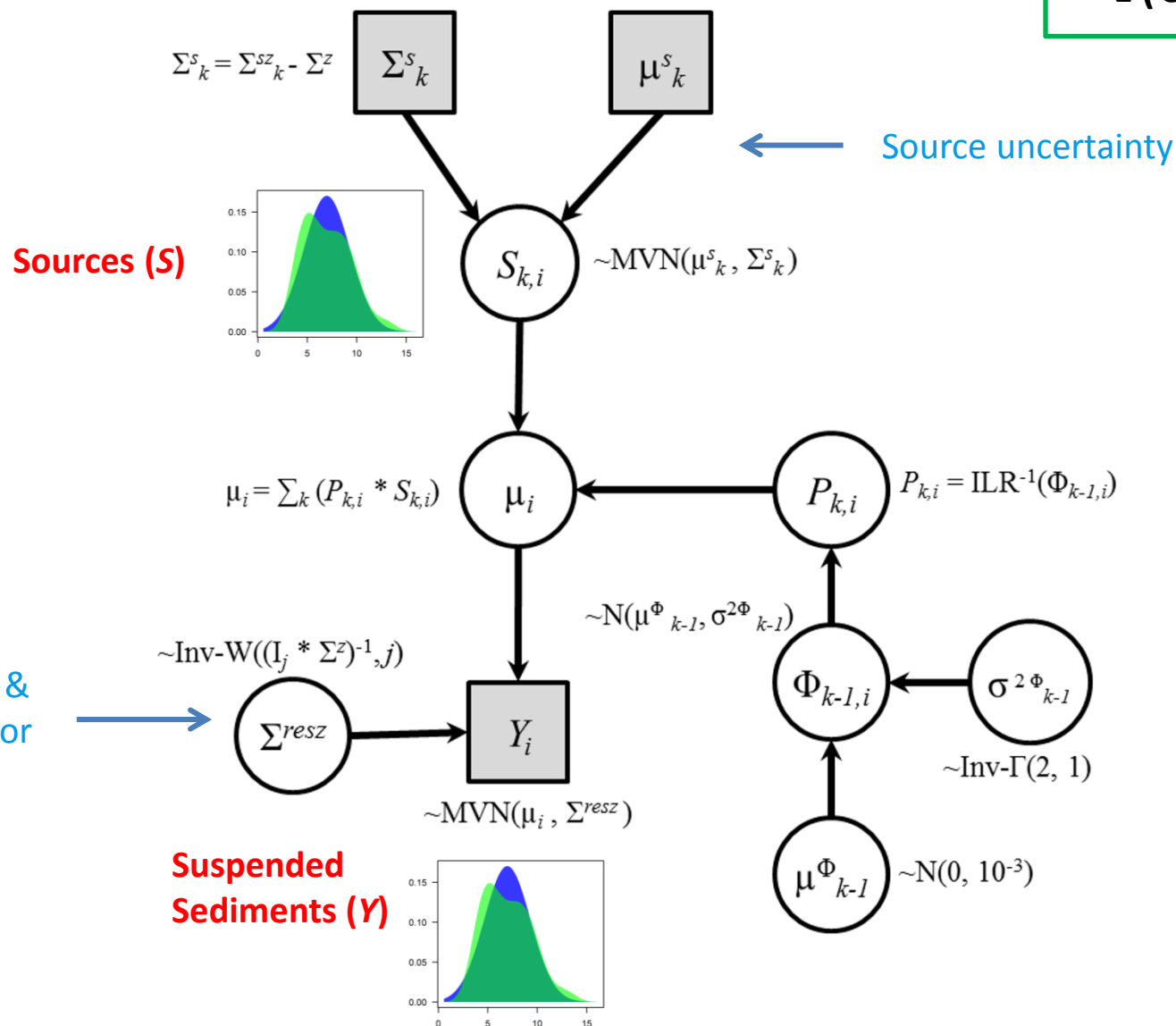
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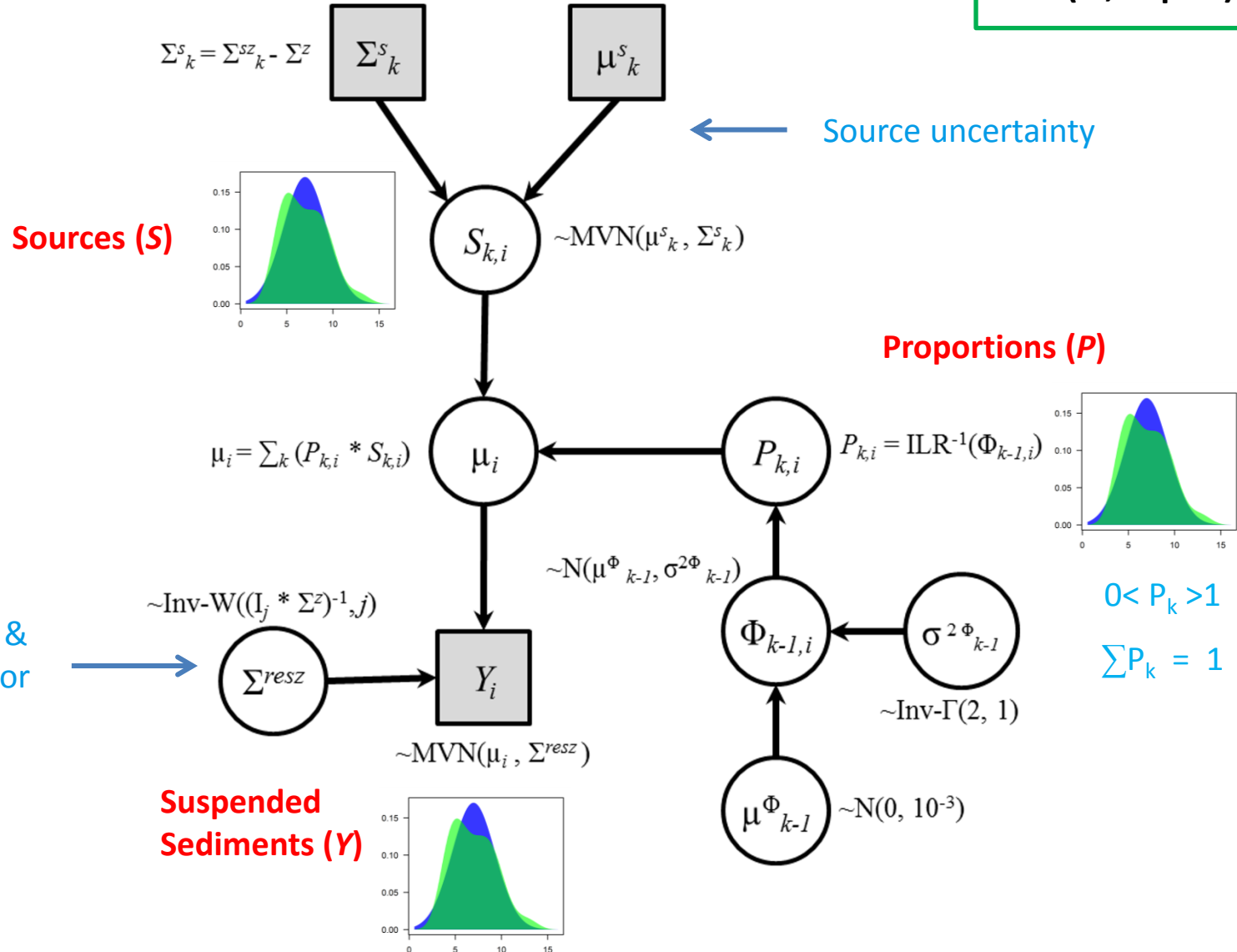
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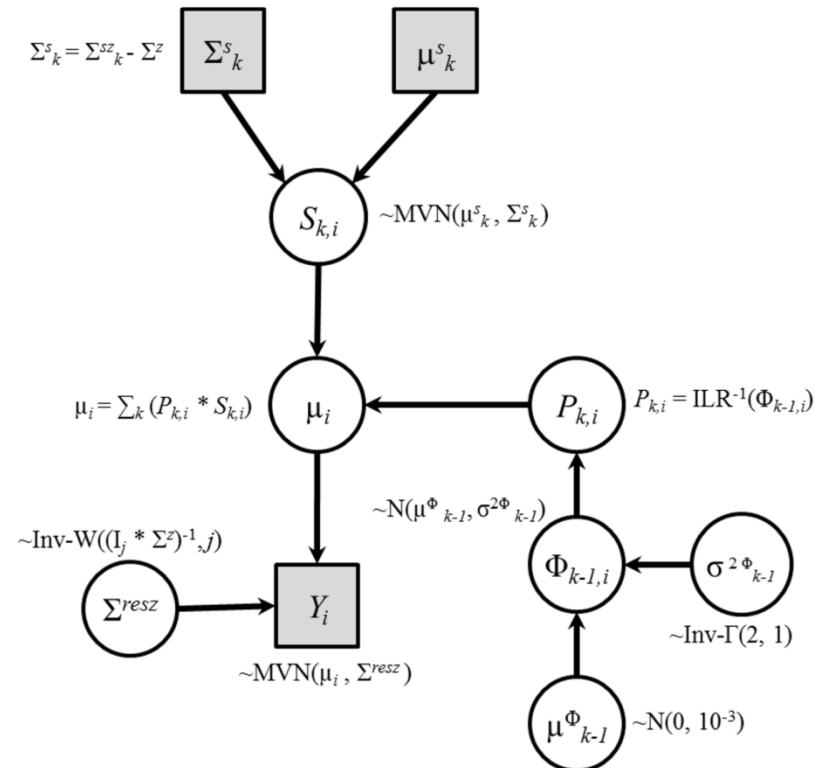
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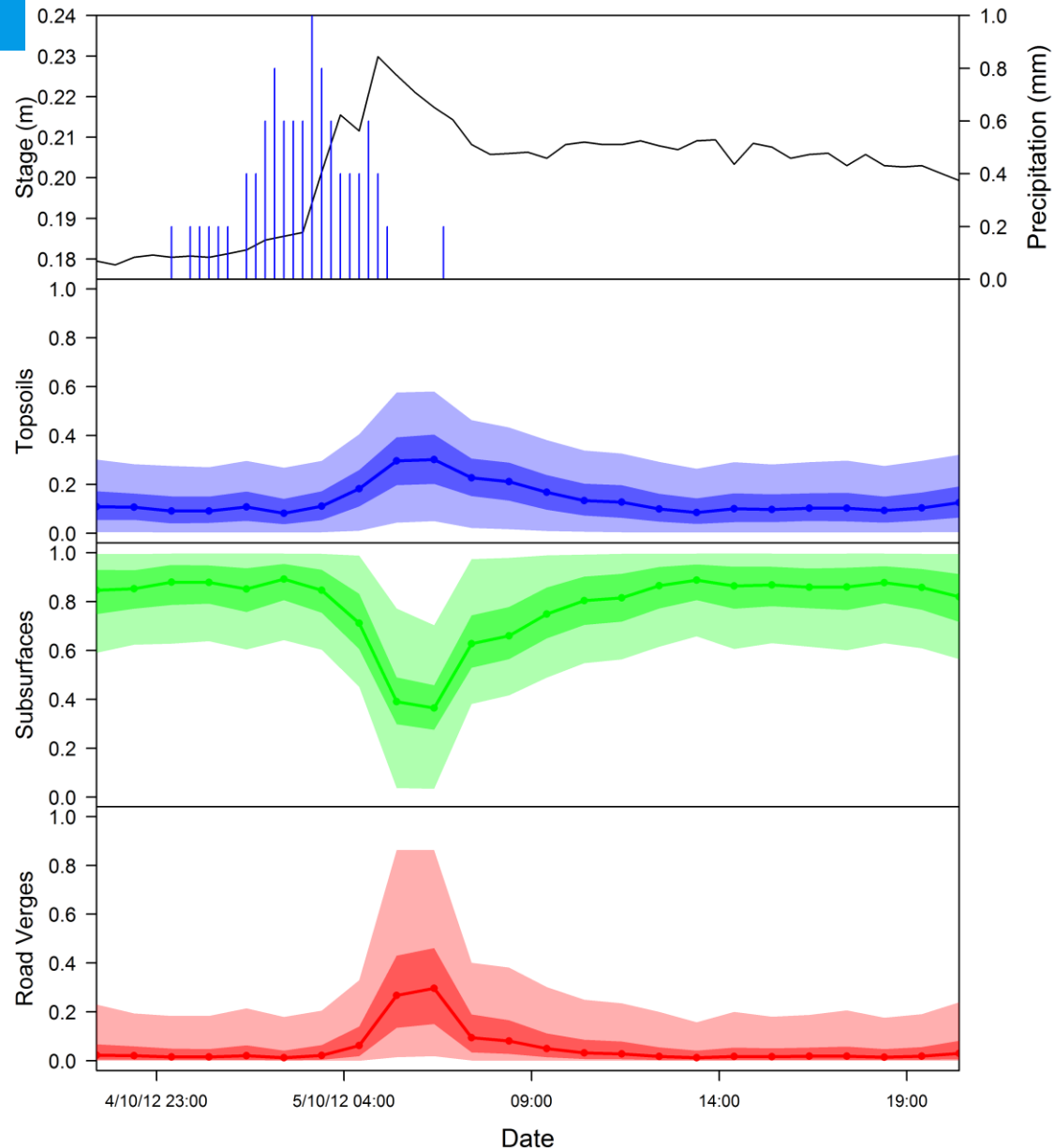
Bayesian Mixing Model

- Coherent, flexible framework for uncertainty analysis.
- Posterior distributions not fixed at measured values, thus can relax assumption samples representative of entire catchment variability – **conservative tracer behaviour**.
- Organic matter & particle size corrections, if required, are implicitly incorporated within **residual error** term through variability in Y .



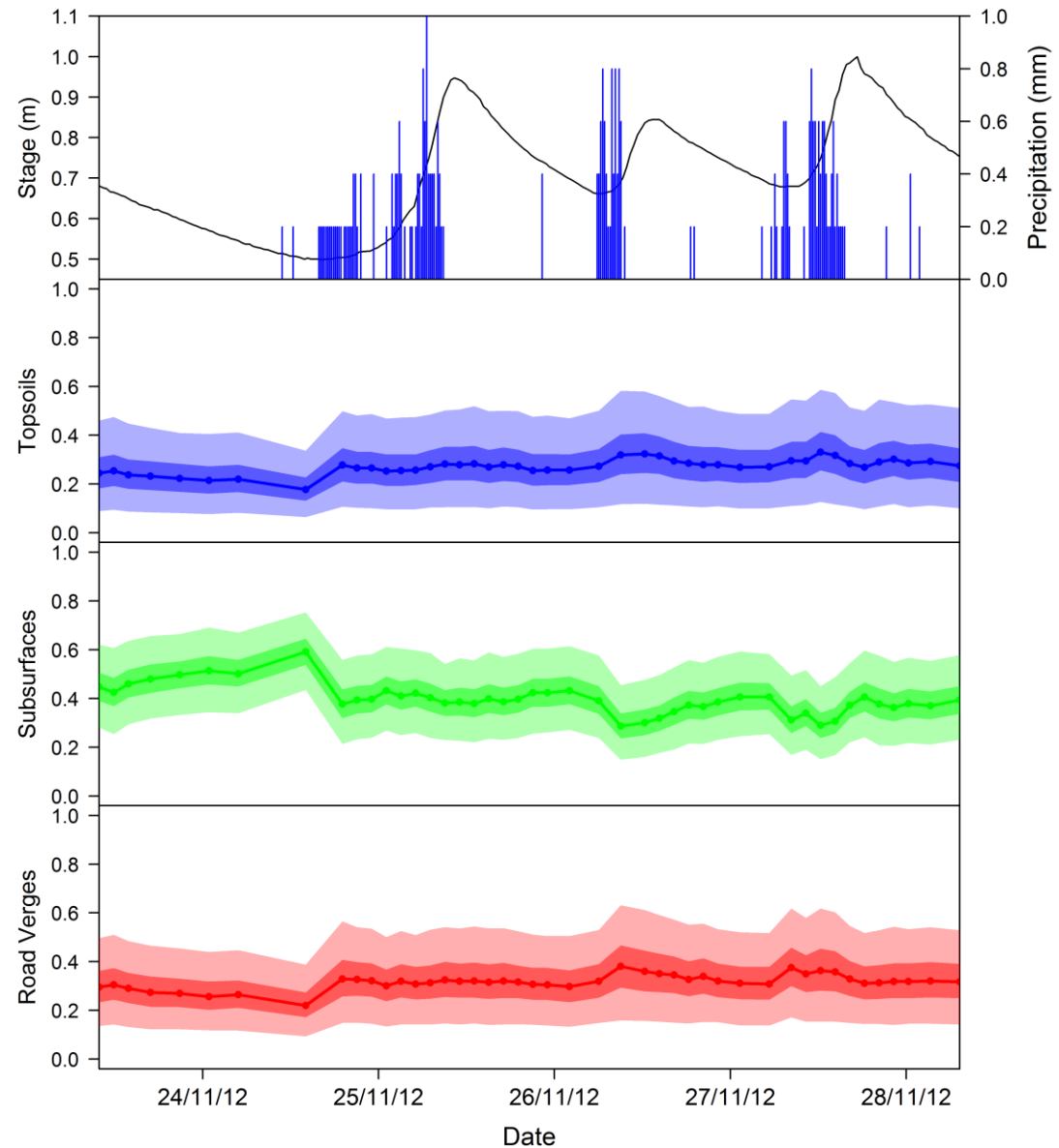
4-5th October 2012

- **10.2 mm** rainfall
- 60-minute resolution.
- Response within **2 hours** post-heaviest rainfall.
- **Subsurface** calcium-rich material dominates pre- & post-event.
- Rapid increase in carbonate-depleted **Topsoil** and **Road Verge** contribution as surface runoff generated.



24-28th November 2012

- **36.4 mm** rainfall
- **Increase in Road Verge** and **Topsoil** contribution as rainfall events pass through the catchment generating surface runoff.
- **Declining** contribution from **subsurface sources** as successive precipitation episodes increase importance of surface sources.



Take Home Messages

- Spectroscopy provides **rapid, accurate, inexpensive** and **non-destructive** method for high-temporal resolution sediment source apportionment.
- The **Bayesian mixing model** procedure provides a coherent framework to quantify all perceived uncertainties.



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Thank You for Listening

HYDROLOGICAL PROCESSES

Hydrol. Process. (2013)

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Combining two filter paper-based analytical methods to monitor temporal variations in the geochemical properties of fluvial suspended particulate matter

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